A POST-ASSESSMENT EXAMINATION OF MODEL DIAGNOSTICS FOR THE 2010 STOCK SYNTHESIS MODEL FOR BIGEYE TUNA

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SUMMARY

A re-examination of the 2010 bigeye tuna stock synthesis modeling configuration and model diagnostics are presented. The configuration is patterned after previous bigeye tuna assessment work presented in the 2005 and 2010 meetings. The primary goal of this report is to provide a basis for discussion, review, and critique on the partitioning of the fleets as well as the spatial and seasonal aspects of the configuration. Because the data used in the model is from the previous assessment conducted in 2010 and has been updated, any actual management advice that may emerge from this model and configuration are not suitable for current (2015) management purposes. Examination of the most recent catch data showed that the percent of landings accounted for by the purse seine gear is increasing. This has led to a down turn in the yield-per-recruit and a higher ratio of age 1-to-age 2+ fishing mortality. The evolution of the fishery from a predominantly longline catch to one of increasing purse seine catch violates important assumptions of the stock-production model, making an integrated model approach more appropriate.

RÉSUMÉ

Un réexamen de la configuration de 2010 de la modélisation Stock Synthèse du stock de thon obèse et les diagnostics du modèle sont présentés. La configuration a été conçue suite au précédent travail d'évaluation du thon obèse présenté aux réunions de 2005 et 2010. Le principal objectif de ce rapport est de fournir une base de discussion, d'examen et de critique sur la séparation des flottilles ainsi que les aspects spatiaux et saisonniers de la configuration. Étant donné que les données utilisées dans le modèle proviennent de l'évaluation précédente réalisée en 2010 et que celles-ci ont été mises à jour, tout avis de gestion susceptible de découler de ce modèle et de la configuration n'est pas adapté à des fins de gestion actuelle (2015). L'examen des données de capture les plus récentes a montré que le pourcentage des débarquements comptabilisés des senneurs est en augmentation. Cela a conduit à une baisse de la production par recrue et un ratio plus élevé de la mortalité par pêche des spécimens d'âge 1 à 2. L'évolution de la pêche, passant d'une capture réalisée principalement à la palangre à une augmentation des prises des senneurs, compromet d'importants postulats du modèle de stock-production, de sorte qu'une approche de modèle intégré s'avère plus appropriée.

RESUMEN

Se presenta un nuevo examen de la configuración del modelo Stock Synthesis para el stock de patudo de 2010, así como los diagnósticos del modelo. La configuración sigue el diseño de los de trabajos previos de evaluación de patudo presentados en las reuniones de 2005 y 2010. El objetivo principal de este documento es proporcionar una base para la discusión, revisión y crítica de la división de las flotas, así como los aspectos espaciales y estacionales de la configuración. Dado que los datos utilizados en el modelo proceden de la evaluación previa realizada en 2010 y han sido actualizados, cualquier asesoramiento en materia de ordenación derivado de este modelo y configuración no es adecuado para propósitos actuales de ordenación (2015). Un examen de los datos más recientes de captura mostró que el porcentaje de desembarques realizados con artes de cerco se ha incrementado. Esto ha producido un descenso en el rendimiento por recluta y una ratio más alta de mortalidad por pesca de ejemplare con edades 1 a 2+. La evolución de la pesquería que ha pasado de un predominio de las capturas de palangre al incremento de las capturas de cerco incumple importantes supuestos del modelo de producción de stock, haciendo que sea más apropiado aplicar un enfoque de modelo integrado.

KEYWORDS

Mathematical models, Stock assessment, Yield/recruit
1. Introduction

The ICCAT Bigeye Tuna Species Group has been preparing for a statically integrated model approach to the assessment of the stock since 2002 (Myabe 2005). However, as ICCAT assessments move towards model of increasing complexity it is becoming more and more challenging to complete the entire assessment process within the time frame generally allowed for the assessment meetings. Often times there are only brief time periods between successful model runs that achieve group consensus and completion of the assessment advice. In an effort to allow more time to fully comprehend and evaluate previous modeling exercises this paper uses the 2010 bigeye tuna assessment data and results to attempt to provide to the 2015 data preparatory meeting a more continuous and comprehensive process of diagnosing the available data as well as the modeling process. It is hoped that by examination of the data in this manner will help identify possible data outliers as well as offer a chance to more fully evaluate model fit residuals so as to get a “head start” on the latest assessment efforts.

2. Material and methods

This paper uses the data and stock synthesis assessment model from the 2010 BET assessment (ICCAT 2011). The model structure was kept similar to the previous MFCL 2010 model, with 8 annual age classes, three fishing area (Figure 1), and four quarters of three months each. The data and time periods used in the model are shown in Figure 2. The model structure was adopted and intentionally kept consistent with Miyabe (2005) MULTIFAN-CL model to facilitate comparisons between the two platforms.

Most often whenever a multi-area and multi-season assessment model is used annual recruitment must be somehow distributed within those areas and seasons. In this case recruitment was fixed to occur in equal proportions in each of the four calendar quarters (i.e. 25%), with 5% occurring in areas 1 and 3 and 90% occurring in area 2. Upon reaching age_1, fish were allowed to move between areas 1 and 2, and areas 2 and 3. The SS model used the MFCL maturity-at-age schedule that was used in the 2007 bigeye tuna assessment.

Biological values (natural mortality, von Bertalanffy growth parameters, and variation in length at age, length-weight relationship, maturity, and spawning contributions by age) were fixed at values identical to the 2005 and 2010 values. Growth cohorts were not used; nor were time series changes in fishery selectivity, catchability, or biological parameters.

Estimated parameters included movement parameters, R0, steepness, annual recruitment deviations, initial fishing mortality, overall fleet catchabilities, and length-based selectivity parameters. A total of 117 parameters were estimated.

3. Results

Fit to indices of abundance

The purse seine fisheries from Spain, France, and Venezuela were broken into three separate fleets based on time stanzas (Table 1). The Ghanaian purse seine fishery was combined with the Ghanaian bait boat fishery. This created five purse seine indices of abundance in which to fit the assessment model to (fleets 1-5, Table 1). The estimated selectivity of these fleets indicates that this gear fishes mostly on age_1 fish, thus the model sees these as recruitment indices of abundance. Generally having an index of recruitment is very helpful to the assessment process. However, the effort of purse seine gear is notoriously hard to characterize so CPUE estimates are often not thought to be very reliable. If considered end-to-end, the four purse seine CPUE time series could be depicting an early “ramp up” phase in the 1970 and then a very consistent trend to the end of the time series in 2005 (Figure 3).

In general the bait boat indices of abundance had the greatest degree of year-to-year variation (Figure 4 and 5). Bait boat selectivity was very similar to that of purse seine gear (i.e. focused on young fish), so assuming that both should track recruitment, the model would expect these two indices to be similar over the time period in which they overlap. The residual pattern to the fit of these indices has very little trend suggesting a good fit. However, in this case, it is also indicative of a CPUE time series with little trend and a model fit that is equally without trend. Both the purse seine and bait boat indices suggest that recruitment for the last 30 years has varied about a mean value with little directional trend. For caveats on this fit see discussion.
The longest, unbroken time series of CPUE data were those of the longline gear. The residual patterns for the CPUEs for areas 1 and 2 show a lack of fit for the approximately 15 years of the time series (Figure 6). This time period corresponds to the period that the Japanese longline fleet began to shift effort away from yellowfin tuna and on to bigeye tuna. It is conceivable that this transition may have a certain learning curve associated with it, as well as a slow but gradual shift to deeper sets to better target bigeye tuna. From the 2010 assessment:

Not accounting for changes in targeting strategies (i.e., when fishing effort is redirected towards another species) may introduce bias into the use of CPUE time series as a proxy of apparent abundance. In the case of longline fisheries, owing to the development of the high value sashimi market in Japan and the progress made in terms of freezing onboard industrial longliners (-50°C in the early 1970s), frozen bigeye from distant-water fisheries appeared as a complement to bluefin in the sashimi market as early as 1975 and that it became the main component since 1985. As a consequence, new fishing strategies were adopted by the main longliners fleets, first targeting yellowfin tuna and albacore for canning, then shifting to high-priced species such as bluefin tuna, southern bluefin tuna and bigeye tuna for the sashimi market. Changes in the fishing grounds, as well as modifications in the fishing gear (from regular to deep longline) were made approximately in 1976-1977 for the Japanese fleet, after 1980 for Korea and in the early-1990s for Chinese Taipei.

The indices from the “other” longline fleets (Figure 7) show a similar pattern as those of the Japanese fleet. That is, a gradually declining trend over the past forty years.

When the residual mean square error is examined across the fleets it is apparent that the bait boat CPUEs (fleets 5-9) resulted in the least amount of agreement with the rest of the data within the model (Figure 8). This does not imply that any of the indices of abundance are any more accurate than any others. It merely quantifies the agreement of an individual CPUE to the rest of the data in the model. These values could be used to re-weight the indices, giving more weight to those that are in better agreement and less to those that are not.

Fit to length composition data

The estimated selectivity patterns show very clearly that the purse seine targets age_1 fish, bait boats age_2, and longline age_2 plus (Figure 9). This is important to recall these selectivities when considering the trends in their respective CPUEs as the selectivities show that the indices are tracking different age groups of the population. Figure 10 shows the length composition for the first six fleets, purse seine and bait boat, and how all six fleets tend to catch the smaller age_1 and age_2 fish, respectively. The length composition of the other three bait boat fleets are shown in the top three panels of Figure 11. These fleets tend to catch mostly age_2 fish. Finally, the bottom three panels of Figure 11 and the three panels of Figure 12 show the longline length compositions, which tend to catch the largest fish.

Examination of the purse seine length data suggests that (1) there are two size groups of fish being reported by the purse seine fishery, small and large, and (2) that use of time varying selectivity may more accurately capture the historic operation of the purse seine fleets (Figure 13). At the beginning of the data, from 1965, to about 1978 the length compositions suggest a fishery that selected mixed lengths, but sample sizes where low during this time period. From 1979 onward however the fishery selected mostly 50 cm (age_1) fish. Data from the second time stanza of this fishery showed similar trends (Figure 14). Fleets 3 (late purse seine, free schools) show a distinctly bimodal distribution, quite possibly from at-sea transfers from other gears (Figure 15). The larger lengths may be better defined by other gear types so that their removals are more accurately characterized. Alternatively, a more flexible selectivity function could be used in an effort to capture the bimodal distribution. Likewise for fleet 4 as it shows very similar patterns (Figure 16). The diagonal pattern seen the 50 cm fish could be explained by the within year, relatively fast, growth of those fish as grow through the peak of the selectivity curve. A time break in the selectivity of this fleet (fleets 4) may also be appropriate in or around the year 2002.

The length data from the bait boat fisheries show the most year-to-year variation (Figure 17-20). However, these fleets also have the smallest sample sizes. Fits to the longline length data are fairly consistent, however there is evidence of smaller than expected fish are being landed, but not necessarily captured, by this gear. As with the purse seines, the bait boat tend to fish on the youngest fish, mostly age 1 and age 2. The length compositions from Fleet 9, the northern bait boat fishery in area 1, were quite different than the other bait boat fisheries (Figure 21). This fleet fishes of the Azores and catch not only smaller fish (~60-70 cm) but also lands larger fish between 150 and 200 cm. Of note however is the decreasing number of observations of 200 cm fish over time.
The length compositions and fits for the six modeled longline fleets are shown in Figures 22-32. Perhaps the most noteworthy points that these plots reveal that are most pertinent to the data preparatory meeting is the possibility of outliers within the data. Figures 33 shows the fit to the length compositions by fleet with the seasons combined, and Figure 34 and 35 show the fits to the length compositions by fleet and by season.

Several movement parameters were estimated within the model, being informed by the tagging data. The resulting estimated functions suggested that young fish move the most with the rate of movement dropping considerably after age_4 (Figure 36). An evaluation of the quality of the information contained within the tagging data should be conducted before it is used again. Factors such as tag loss and non-reporting should also be evaluated.

To the extent that the 2013 landings are up to date, they are the lowest they have been for at least two decades (Figure 37). The percent of the total landings made up by the longline gear is decreasing while the percent accounted for by purse seine has been increasing (Figure 37). Presumably, because the purse seine CPUE have remained constant (and possibly hyper-stable), and the purse seine catch has increase, the model has estimated that recruitment has remained relatively stable for the period 1950-2010 (Figure 38). The possible hyper-stability of the purse seine fishery and CPUE may be resulting in an over estimation of recruitment. However, because the longline CPUE and landings have decreased over the past decade the estimate of spawning stock biomass has decreased (Figure 38). This is very likely why the model estimates a high degree of productivity for this stock. The model further estimated that the ratio of age_1 fish to age_2+ in the population has been approximately 1:1 in the past three decades. This could be a function of over estimating recruitment as discussed above. But that the ratio of the catch has been consistently favoring age_1 fish (Figure 39). For 2010 the estimates are that the catch is made up of approximately 70% age_1 fish and 30% age_2+ and that this trend continues to increase.

The shift from larger, older fish from the longline gear to smaller, younger fish from the purse seine gear seems to have led to down turn in the yield-per-recruit (YPR) of the overall stock (Figure 40). YPR has been increasing in the overall fishery up until around the year 2000, but since then has begun decreasing annually. Coincident with this decline there was sharp upturn in the ratio of fishing mortality on age_1 to age_2+ fish with age_1 fish experiencing over twice the fishing mortality than age_2+ fish in 2010 (Figure 40).

4. Discussion

The gears types used to prosecute the bigeye tuna fishery have very different age-specific fishing mortalities (i.e. selectivities). For this reason using all the available CPUE data simultaneously does not satisfy the assumptions of a standard stock production model, which assumes all fish are fully selected. Because the make-up of the catch is trending towards increasing young fish (age_0 and age_1) and decreasing older fish (age_2+) violation of this assumption may become increasingly troublesome. However, the previous assessment (2010) used only the longline CPUEs to fit the production model that provided management advice, so this was not an issue. But this approach ignores the fact that fishing pressure has shifted from older fish to younger fish and makes the stock-production type model likely not the best platform for this particular stock and combination of fisheries.

The model is depicting a population with steady recruitment and declining number of adults. This may be because the young fish indices (purse seine and bait boat) are staying relatively flat while the adult indices (longline) are declining. Because of these two trends, the model is estimating a very productive stock where recruitment is being provided by sequentially decreasing spawning stock biomass. This makes the assumption that the purse seine indices are providing a clear and accurate indication of recruitment strength one of critical importance. Consequently, the question of how to quantify “effort” for the purse seine CPUE becomes critical. If the young fish indices are not considered reliable, or perhaps even biased, then perhaps other measures of stock status could be considered. The 2010 assessment reported that both the MFCL and SS models showed that yield-per-recruit had reached a peak and was being fished beyond the maximum level (Figure 40). Another benchmark that ICCAT is using in bluefin tuna is F0.1. Given the unknown quantity and quality of the estimates of steepness, these two benchmarks may offer viable alternatives as they do not require estimates of productivity.

The model configuration described here, from Miyabi et al. (2005), is a very legitimate starting point for continued use of the SS platform. However this particular configuration should be considered just one of many possible starting points and should not at all be considered beyond review and possible refinement or possible simplification. The SS platform has certain capabilities that were not available in MFCL at the time of the Miyabi et al. (2005) work. Features such as time varying parameters would allow for the possibility of combining certain fleets and allowing characteristics such as catchability or selectivity to change over time rather than splitting the single fleet into multiple fleets in an effort to capture these time varying aspects.
One topic of ongoing discussion is just how complex our assessment models need to be in order to justify their use over a simpler model. This is difficult to address without completing perhaps a simulation study where the operating model simulates the complexity of the fishery and the estimation model attempts to capture that within a simpler model. Another approach would be to use a complete Management Strategy Evaluation (MSE). Coupled with the question of model complexity is how to either choose among a set of model outputs or between models of varying complexity, or how best to combine the results of several modeling approaches and their associated uncertainty into one characterization of the status of the stock. This was the situation at the previous bigeye tuna assessment meeting with the number of models and formulations adding to the task of completing the assessment and management advice in a timely manner. It may be advantageous and perhaps more objective to make determinations of how multiple models and multiple modeling results will be dealt with or characterized before the assessment workshop (i.e. before or during the data preparatory meeting) rather than during the assessment workshop itself.

References


Table 1. Definition of fisheries used in the SS model (adopted from the 2010 BET assessment).

<table>
<thead>
<tr>
<th>Fishery</th>
<th>Gear</th>
<th>Nation</th>
<th>Area</th>
<th>Years covered</th>
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<tbody>
<tr>
<td>1</td>
<td>PS</td>
<td>France, Spain and others (early)</td>
<td>2</td>
<td>1965 - 1985</td>
</tr>
<tr>
<td>2</td>
<td>PS</td>
<td>France, Spain and others (transition)</td>
<td>2</td>
<td>1986 - 1990</td>
</tr>
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<td>2</td>
<td>1991 - 2005</td>
</tr>
<tr>
<td>4</td>
<td>PS</td>
<td>France, Spain - FAD</td>
<td>2</td>
<td>1965 - 2005</td>
</tr>
<tr>
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<td>BB</td>
<td>Ghana BB+PS</td>
<td>2</td>
<td>1973 - 2005</td>
</tr>
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<td>6</td>
<td>BB</td>
<td>Other tropical nations (south)</td>
<td>2</td>
<td>1962 - 2000</td>
</tr>
<tr>
<td>7</td>
<td>BB</td>
<td>Other tropical nations (north, early)</td>
<td>2</td>
<td>1965 - 1979</td>
</tr>
<tr>
<td>8</td>
<td>BB</td>
<td>Other tropical nations (north, late)</td>
<td>2</td>
<td>1980 - 2005</td>
</tr>
<tr>
<td>9</td>
<td>BB</td>
<td>Portugal, Spain (North Islands)</td>
<td>1</td>
<td>1965 - 2005</td>
</tr>
<tr>
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<td>Japan</td>
<td>3</td>
<td>1961 - 2005</td>
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<tr>
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<td>14</td>
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<tr>
<td>15</td>
<td>LL+Uncl</td>
<td>Others (US, Chinese Taipei, etc.)</td>
<td>3</td>
<td>1966 - 2005</td>
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</table>

Figure 1. Areas definition used in the SS model configuration.
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